

UNIVERSITY OF MESSINA

PhD in  
"ENGINEERING"  
XXXIX Cycle

**Battery Management System**

**PhD Student: Eng. Marco Caselli**

**Tutor: Prof. Salvatore De Caro**

# Battery Management System

The BMS is an electronic device that monitors the operation of rechargeable batteries, preventing dangerous or suboptimal operating conditions. Its topic is to ensure safety, reliability, and efficiency, preventing the battery from operating outside its safe operating range.

The project consists in the study and development of a Smart Battery Management System for automotive applications, using the STMicroelectronics EVAL-L9963E-MCU evaluation board , based on the L9963E chip.

## Functions

The main functions of an electric vehicle battery management system are:

- Battery protection to prevent operation outside its safe operating area.
- Battery monitoring by estimating the battery state of charge ( SoC ) and state of health ( SoH ) of the battery pack during charging and discharging.
- Battery optimization through cell balancing that improves battery life and capacity, thus optimizing driving range for hybrid (HEV), plug-in hybrid (PHEV), and fully electric (BEV) vehicles.

## Smart BMS

The Smart BMS is an advanced version of the management system that integrates more sophisticated algorithms, distributed computing capabilities and connectivity cloud compared to a standard BMS

The main features of a Smart BMS are

- integration with IoT (Internet of Things ) technologies and remote connectivity , to enable continuous monitoring and predictive diagnosis ;
- predictive and machine learning algorithms , which allow a more accurate estimate of the state of charge, health status and degradation conditions ,
- safety , achieved through robust communication protocols , multi-level protections and the ability to react in real time to critical conditions
- architectures , suitable for high voltage systems and large battery packs .

To verify and experiment with the described functions , the **EVAL-L9963E-MCU evaluation board with L9963E chip** was used, **whose characteristics are:**

- Measures 4 to 14 cells in series, with 0 $\mu$ s desynchronization delay between samples
- Coulomb counter that supports battery pack overcurrent detection in both on and off state .
- Fully synchronized current and voltage samples.
- 16-bit voltage measurement.
- 2.66 Mbps isolated serial communication with regenerative buffering, supporting dual access ring.
- Transformer-based isolation.
- Up to 4 analog inputs for NTC sensing, plus PCB temperature sensing.
- SPC574S64E3 Embedded Microcontroller with 32-bit Power Architecture MCU for Automotive
- Integrated L9001 regulator as a power supply for microcontroller.
- Dedicated hot- plug circuit .

## Software

The STSW-L9963E software is a PC graphical interface developed to configure and manage the EVAL-L9963E-MCU board, used in Battery Management Systems (BMS) with the L9963E chip. It allows:

- to control all the functions of the chip,
- Monitor and diagnose your system, record and export data for offline analysis .

# Graphical Interface



# Configuring voltage thresholds

L9963\_evaluation\_GUI\_V 1.805 validation--- STMicroelectronics

Voltage & current & temperature Configuration & PCB open wire diagnostic & sleep mode Diagnostic - information Diagnostic - raw upstream frame

Ver 1.805 Automotive

1

GPIO3\_OT\_TH 0,000 GPIO4\_OT\_TH 0,000 GPIO5\_OT\_TH 0,000 GPIO6\_OT\_TH 0,000 GPIO7\_OT\_TH 0,000 GPIO8\_OT\_TH 0,000 GPIO9\_OT\_TH 0,000

GPIO3\_UT\_TH 0,000 GPIO4\_UT\_TH 0,000 GPIO5\_UT\_TH 0,000 GPIO6\_UT\_TH 0,000 GPIO7\_UT\_TH 0,000 GPIO8\_UT\_TH 0,000 GPIO9\_UT\_TH 0,000

threshVcellIOV 4,250 VBATT\_SUM\_OV\_TH 59,500 CSA\_THRESH\_NORM [mV] 0,000000 ADC\_FILTER\_SOC 290 us

threshVcellUV 2,800 VBATT\_SUM\_UV\_TH 39,200 adc\_ovc\_curr\_threshold\_sleep [mV] 0,000000

Ratio abs 3 sel Ratio abs 7 sel  
Ratio abs 4 sel Ratio abs 8 sel  
Ratio abs 5 sel Ratio abs 9 sel  
Ratio abs 6 sel

GPIO\_CONV OFF CELL\_TERM\_CONV OFF SOC OFF  
GPIO\_TERM\_CONV OFF BAL\_TERM\_CONV OFF HWSC OFF

CoulombCounter\_en OFF  
comm\_timeout\_dis OFF

PCB open wire diagnostic

C0 C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14

CONF\_CYCLIC\_EN OFF NCYCLE\_GPIO\_TERM 0 NCYCLE\_HWSC 0  
CYCLIC\_UPDATE OFF NCYCLE\_CELL\_TERM 0 ADC\_FILTER\_CYCLE 0  
NCYCLE\_BAL\_TERM 0 TCYCLE\_SLEEP 0  
NCYCLE\_GPIO 0 ADC\_FILTER\_SLEEP 0

PCB open wire ACK  
Enter sleep mode ACK

2

mosi	VCELL_THRESH_UV_OV	miso
17	0	0
16	0	0
15	1	0
14	0	0
13	1	0
12	1	0
11	1	0
10	0	0
9	1	0
8	1	0
7	0	0
6	1	0
5	1	0
4	1	0
3	1	0
2	0	0
1	1	0
0	1	0

3

Addr xB CRC x2C Write Dev ID 1

4

mosi C4585DBDAC miso 0

Configuration registers

VCELL\_THRESH\_UV\_OV Single write/read

5

Save configuration Load configuration

6

COM13 Fn B0 COM ACK

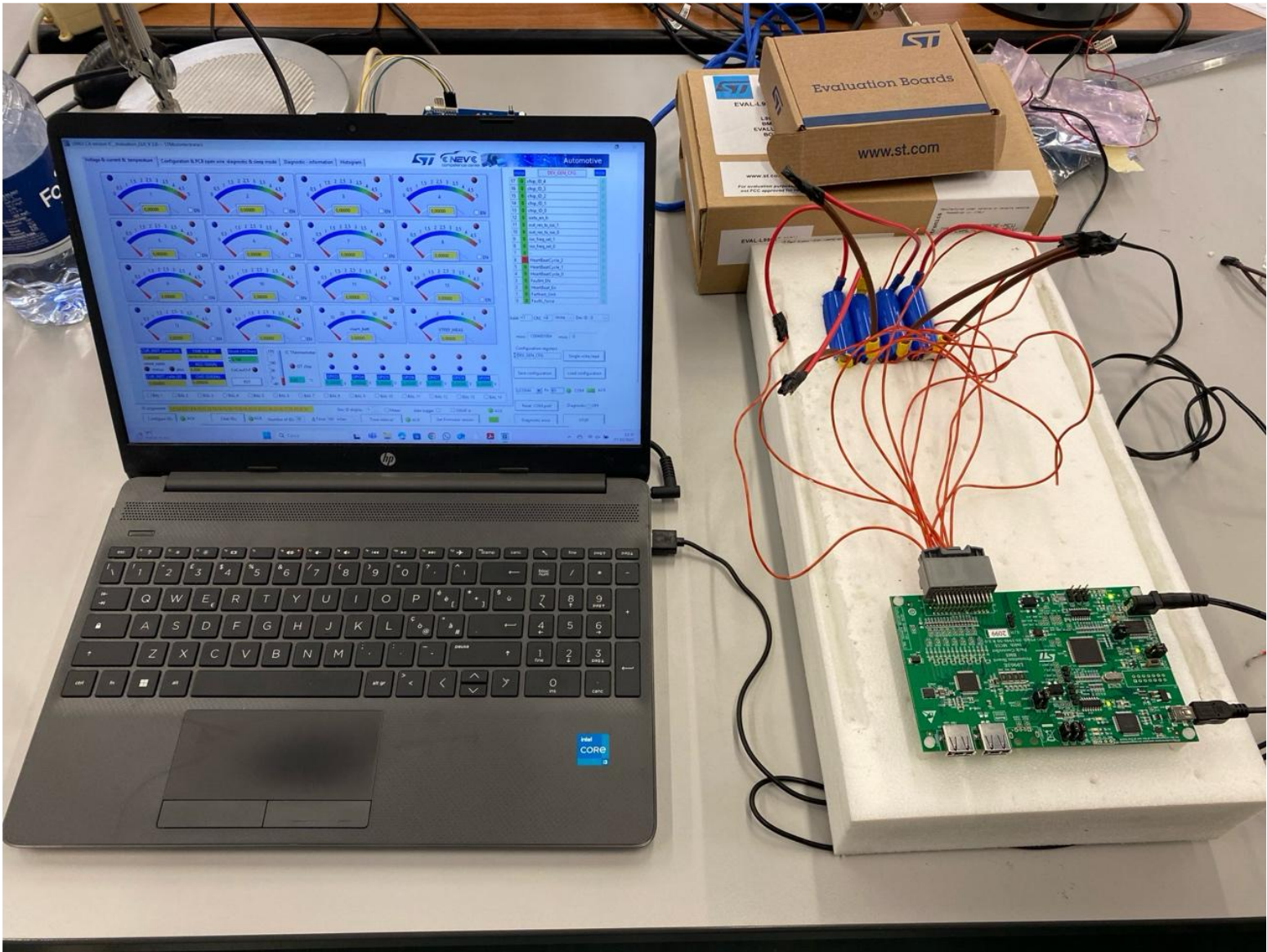
Reset COM port Diagnostic OFF

Configure IDs ACK Clear IDs ACK Time interval ACK Configure device ACK Get Firmware version 1.5

Diagnostic once STOP



Test bench



## Cells



The cells used are 18650 lithium-ion type

## Measures

The measurements were recorded under controlled charging and discharging conditions, so as to observe the trend of the variables over time and verify the system's response to any imbalances between cells .

The data obtained form a basis for further analysis and confirm the consistency between the performance of the board and the typical functionality of a smart BMS .

The work carried out has allowed us to systematically study the structure, functions and potential of a Smart Battery Management System intended for automotive applications . After an analysis of the theoretical principles underlying the operation of battery management systems and the techniques for estimating fundamental parameters, the experimental activity has allowed us to concretely understand how hardware and software solutions can be integrated into an intelligent and reliable system.



## Future developments

It will be possible to introduce more advanced algorithms for the estimation of the State of Charge and the State of Health of the cells, so as to obtain more precise measurements and more efficient energy management

The adoption of active balancing techniques, which allow the energy to be redistributed between the cells more effectively than passive methods , increasing the autonomy and life of the battery pack

Integrate the system with intelligent communication systems, such as vehicle-to-grid (V2G ) networks , which allow energy and information to be exchanged with charging

